Slovak agricultural farms in different regions – comparison of efficiency

Slovenské poľnohospodárske podniky hospodáriacich v rôznych výrobných podmienkach – komparácia efektívnosti

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Abstract: This paper presents the results of stochastic parametric approach used in estimation of production frontier. The estimation of output oriented technical efficiency was based on the Stochastic Frontier analysis with Cobb-Douglas production function. The model also included a dummy variable which expressed production conditions in which Slovak farms are operating. We divided farms into two groups regarding production conditions: productive regions (PR) and less favorable area (LFA) regions. The data set included 79 Slovak farms operating in different regions in the 2003–2005 time periods. The following input variables are included in the model: capital, material, labour and agricultural land according to the LPIS system. Total output was used as the output variable. From the achieved results, we can conclude that the significant statistical differences in average technical efficiency were detected only in year 2005 between the farms of the mentioned production conditions. A higher level of variability in technical efficiency was detected in farms operating in productive regions compared to technical efficiency of farms in the LFA regions.

Key words: less favorable area (LFA), subsidy, stochastic production frontier, panel data, output – oriented technical efficiency, Cobb-Douglas production function

Abstrakt: V príspevku sú prezentované výsledky stochastického parametrického prístupu odhadu produkčných hraníc. Na báze odhadu stochastickej produkčnej funkcie s využitím Cobb-Douglasovej produkčnej funkcie sú odvodené outputovo orientované miery technickej efektívnosti. Vzhľadom k rozdielnemu charakteru výrobných podmienok boli do modelu implementované kvalitatívne premenné, ktoré zohľadnili kvalitu výrobných podmienok. Údajovú základňu tvoria podnikové údaje 79 slovenských poľnohospodárskych podnikov hospodáriacich v rôznych výrobných podmienkach v rokoch 2003 až 2005. Komparatívna analýza rozdeľuje poľnohospodárske podniky do dvoch skupín : podniky hospodáriace v dobrých výrobných podmienkach t.j. podniky hospodáriace v produkčnej oblasti a podniky hospodáriace v znevýhodnených podmienkach. Ako vstupné premenné sú uvažované : celkový kapitál, materiál, počet pracovníkov, výmera poľnohospodárskej pôdy podľa systému LPIS a ako výstup celková produkcia poľnohospodárskeho podniku. Z dosiahnutých výsledkov vyplýva, že v roku 2005 existuje štatisticky preukazný rozdiel v priemernej úrovni technickej efektívnosti poľnohospodárskych podnikov. Vyššia variabilita v miere technickej efektívnosti bola zistená v podnikoch hospodáriacich v lepších produkčných podmienkach oproti podnikom hospodáriacim v horších podmienkach (LFA).

Kľúčové slová: znevýhodnené oblasti (LFA), dotácie, stochastické produkčné fronty, panelové údaje, outputovo-orientovaná technická efektívnosť, Cobb-Douglasová produkčná funkcia

The gradual increase of agricultural production in the CEE countries was partially caused by the adaptation process of farms to market economy and the creation of new institutions which would provide efficient distributional channels of agricultural inputs. The level of support in creation of these institutions, dealing with the exchange of inputs and outputs within agricultural market, was reflected in different efficiency of agricultural production (Gow, Swinenn 1998).

It is evident that only in the case of improving conditions in which agricultural subjects are producing, we could expect positive trends in the efficiency development. One of the possible approaches in efficiency measurement is using technical efficiency developed by Koopmans (1951) and Farell (1957).

The selection of a suitable functional form of stochastic frontier production model is one of the most important steps for the specification of econometric model. In the empirical studies of production frontiers, two forms of production frontier, the Cobb-Douglas and the translog function, were the most frequently used. The usage of the Cobb-Douglas form of production frontiers in agriculture of the developing countries and transitive economies could be found in the empirical studies of Sotnikov (1998), Murova et al. (2001). The nonparametric approach of measuring technical efficiency was applied by Fandel (2003), Bielik and Rajčániová (2004), Bielik et al. (2002) in Slovak agriculture. Sojková (2001) applied another approach on the cross-sectional data of 61 Slovak agricultural cooperatives. The output-oriented technical efficiency measures were estimated through the use of the parametric stochastic production frontier model. Covaci, Sojková (2006) focused on two main tasks: verifying the suitability of using the stochastic frontier analysis on a transforming sector, and providing empirical evidence to explain the technical efficiency structure among 24 Slovak farms in the time period 2000–2004.

The usage of the mentioned estimated functions could be found in several empirical studies (e.g. Pitt and Lee 1981). They were devoted to estimating stochastic frontiers and predicted firm-level efficiencies using Cobb-Douglas estimated functions on the basis of firm-specific variables (such as managerial experience, ownership characteristics, etc). The authors have tried to identify the reasons for differences in the predicted efficiencies between firms in an industry.

METHODOLOGY AND MATERIAL

From the methodological point of view, the model Battese and Coelli (1995) will be used. The authors propose a model which is equivalent to the Kumbhakar et al. (1991). This model is suitable for the investigation of determinants of technical efficiency and also permits for panel data.

The Battese and Coelli (1995) model specification for this study could be expressed as follows:

$$\ln(y_{it}) = \beta_0 + \sum_{j=1}^{N} \beta_j \cdot x_{jit} + v_{it} - u_{it}$$

$$i = 1,...,N,\ t = 1,...,T \qquad (1)$$

where:

y_{it} = represents the outputs for i- th Slovak farm (i = 1, 2, ... 79) in T time period (T = 1, 2, 3 and corresponds to 2003, 2004, 2005)

x_{jit} = the j-th input of the i-th Slovak farm in the T-th time period (year)

β = parameters to be estimated by the Battese and Coelli stochastic frontier model

v_{it} = random variables which are assumed to be iid. $N(0,\sigma_V^2)$, and independent of the U_{it}

u_{it} = non-negative random variables which are assumed to account for technical inefficiency in production and are assumed to be independently distributed as truncations at zero of the $N(\mu_{it},\sigma_U^2)$ distribution

$$\mu_{it} = z_{it}\delta \qquad (2)$$

where:

z_{it} = $p \times 1$ vector of variables which may influence the efficiency of the firm

δ = $1 \times p$ vector of parameters to be estimated

Subsequently, u_{it} is

$$u_{it} = z_{it}\delta + w_{it} \qquad (3)$$

where w_{it} = random variable truncation of the normal distribution with zero mean and variance σ^2 such that the point of truncation is $-z_{it}\delta$, i.e. $w_{it} \geq -z_{it}\delta$

The individual firm TE derived from model 2 and 3 in the t-th time period is defined by the following equation:

$$TE_{it} = \exp(-z_{it}\delta + w_{it})$$

It is possible by analogy to realize the parameter estimation like in the model case which assumes a systematically time-varying inefficiency. Various authors are inclined to the mentioned model specification of stochastic production frontier. In several empirical studies, there was found the significant effect of time on the technical efficiency level.

The data set was obtained from the Information Reports submitted by Slovak agribusinesses according to the Slovak accounting regulations and presents the panel data of 79 Slovak farms in three time periods (2003 till 2005). The Slovak farms were divided into two groups based on different production conditions: the farms operating in the productive regions – 54 Slovak farms (PR) and the farms operating in the LFA regions (LFA) – 25 farms. The observed Slovak farms were geographically differently situated and the differences between the regions are significant from the arable land percentage and land quality point of view which is projected into the differences in fertility of the investigated regions.

RESULTS AND DISCUSSION

Specification of the model and variables

In the paper, the one-stage classical (Cobb-Douglas) stochastic frontier model with the implementation of dummy variable for different production regions and interactive terms considering different elasticity of inputs in the different conditions was used.

All variables incoming to the model have been log transformed considering the character of the Cobb-Douglas function. The data set was divided into two groups of farms: the farms operating in productive regions (PR) and the farms operating in less favorable areas (LFA). Production conditions were expressed by dummy variable D (D = 0 for LFA and D = 1 for PR) which was defined according to the land quality. The first group of LFA regions (D = 0) is formed by 25 Slovak farms and the second group of PR region (D = 1) by 54 Slovak farms.

The final estimated log-linear Cobb-Douglas model of the stochastic production frontiers has the following form:

$$\ln TP = b_o + b_1 \ln C + b_2 \ln Mat + b_3 \ln L + b_4 \ln LPIS + b_5 . D + b_6 \ln C \times D + b_7 \ln Mat \times D + b_8 \ln L \times D + b_9 \ln LPIS \times D + (v_{it} - u_{it})$$

where: TP represents the outputs (total production) for Slovak farm i (i = 1, 2, ..., 79). In the model, three independent variables are included: logs of capital (C) and materials (Mat) in thousand SK, labor (L) and agricultural land according to LPIS[1] in hectares

The sample summary statistics for these variables are presented in Table 1. The descriptive statistics of the sample are categorized on the basis of the individual year and different production condition.

Table 2 shows the maximum probability methods estimations. The maximum-probability estimates of the parameters in the Cobb-Douglas stochastic frontier production function models defined by (1), given the specifications for the technical inefficiency effects defined in (3), were obtained using FRONTIER 4.1.

The parameters of the final production frontier model are introduced in the first part of Table 2. In the second part, the table presents three additional parameters associated with the distribution of the overall random effect. The negative value of inefficiency coefficient (delta 1) which represents dummy variable for the time period 2004 indicates a significant positive effect on the improvement of technical efficiency. On the other hand, the positive value of inefficiency coefficient (delta 2) indicates an increasing effect of time period on the inefficiency level.

From the final estimated stochastic frontier model, it is possible to derive two models, one for the Slovak farms operating in the productive regions and one for the Slovak farms operating in the LFA regions.

Productive regions (D = 1)

$$\ln TP = -0.447 + 0.534 \ln C + 0.852 \ln Mat + 0.283 \ln L + 0.133 \ln LPIS$$

LFA regions (D = 0)

$$\ln TP = 0.760 + 0.269 \ln C + 1.114 \ln Mat + 0.710 \ln L - 0.047\, LPIS$$

The coefficients of elasticities are represented by the parameters of the individual variables for Slovak farms operating in different regions. If we look at the comparative analysis of the coefficients for the farms of productive regions and of LFA regions, it could be said that the increase of inputs by 1% would lead to a higher increase of the total production of farms in productive regions. While the input increase of capital usage of by 1% would lead to the increase of the total production by 0.534% in the productive regions, in the LFA regions it would register a smaller increase of the total production (by 0.269 %).

Material increase would probably lead to different influences on the measures of technical efficiency in the surveyed regions. It is probable that one percent increase in material input would lead to the increase of the level of technical efficiency by 1.114 percent in farms operating in the LFA region. The productive region would achieve an increase of technical efficiency by 0.852 percent if raising material input by one percent. This fact could lead to the conclusion that farms operating in the LFA have deficits in material inputs. Results from this model advise the farms in the LFA regions to increase material utilisation, which would lead to a greater increase of technical efficiency than the mentioned input.

[1]The Ministry of Agriculture of the Slovak Republic has started carrying out the establishment of the Land Parcel Identification System (LPIS).

Labor influence on the level technical efficiency is highly tied to the overall production conditions in which the investigated Slovak farms are operating. This fact is reflected by the 0.428 percent difference between the productive and the LFA regions in the total production increase caused by one percentage increase in labor inputs. A greater increase of technical efficiency according to the estimated model would be achieved in farms operating in the LFA regions. As a possible cause for this difference, we can regard intensity of labor and capital usage in the surveyed regions. Economic theory suggests the inverse relationship between capital and labor usage. This fact could be supported by the estimated parameters

Table 1. Summary statistics for variables of the stochastic frontier production model

Year – regions	Variable	Mean	Median	Maximum	Minimum	SD	*CV*	*N*
2003 LFA	total production	25 043.31	14 659.00	125 936.00	2 136.00	28 552.00	1.14	25
	capital	71 989.24	70 187.00	181 039.00	3 947.00	42 214.20	0.59	25
	material	71 989.24	70 187.00	181 039.00	3 947.00	42 214.20	0.59	25
	labor	57.80	44.00	172.00	4.00	38.75	0.67	25
	LPIS	2 028.57	1 752.00	6 317.00	560.10	1 329.22	0.66	25
2004 LFA	total production	20 878.46	14 475.00	107 214.00	1 703.00	21 073.19	1.01	25
	capital	6 9561.24	66 832.00	177 523.00	3 948.00	41 006.57	0.59	25
	material	33.05	33.23	50.91	21.97	6.76	0.20	25
	labor	45.32	36.00	152.00	3.00	32.53	0.72	25
	LPIS	1 259.51	1 054.30	2 952.60	323.00	738.58	0.59	25
2005 LFA	total production	20 761.32	14 204.00	104 161.00	1 259.00	20 978.13	1.01	25
	capital	68 447.80	66 853.00	183 421.00	3 966.00	39 537.21	0.58	25
	material	31.65	30.34	46.59	19.82	7.15	0.23	25
	labor	42.12	34.00	138.00	4.00	29.47	0.70	25
	LPIS	1 252.66	1 070.17	2 952.60	320.83	737.91	0.59	25
2003 PR	total production	40 791.30	21 602.50	325 811.00	1 835.00	56 742.54	1.39	54
	capital	73 081.48	36 224.50	383 246.00	2 457.00	85 152.37	1.17	54
	material	43.97	44.80	61.66	28.90	6.99	0.16	54
	labor	62.39	36.00	372.00	2.00	75.83	1.22	54
	LPIS	1 247.83	945.05	5 902.00	1.20	1 174.96	0.94	54
2004 PR	total production	45 239.43	23 773.50	331 209.00	1 491.00	59 980.52	1.33	54
	capital	76 547.56	38 337.50	412 984.00	3 327.00	88 195.49	1.15	54
	material	43.34	44.59	60.44	22.28	8.20	0.19	54
	labor	56.46	32.50	368.00	2.00	71.72	1.27	54
	LPIS	1 262.56	958.24	6 484.00	1.20	1 184.19	0.94	54
2005 PR	total production	40 648.93	21 313.50	319 459.00	1 389.00	57 528.48	1.42	54
	capital	80 517.43	44360.00	416 183.00	2 141.00	92 930.89	1.15	54
	material	43.34	43.19	68.73	22.11	8.25	0.19	54
	labor	53.30	28.00	364.00	2.00	68.42	1.28	54
	LPIS	1 238.65	924.71	6 450.00	1.20	1153.01	0.93	54

Mean = arithmetic mean, SD = standard deviation, *CV* = coefficient of variation, *N* = number of observation

Source: authors' calculations

Table 2. Maximum likelihood estimates of parameters of the Cobb-Douglas stochastic frontier function of Slovak farms

		Parameters	Coefficients	Standard error	*t* ratio
Intercept	I	beta 0	0.760	1.536	0.495
Capital	ln C	beta 1	0.269	0.154	1.742
Material	ln M	beta 2	1.140	0.201	5.661
Labor	ln L	beta 3	0.710	0.181	3.922
LPIS	ln LPIS	beta 4	–0.047	0.114	–0.415
Dummy	D	beta 5	–1.206	1.719	–0.702
D * Capital	D * ln C	beta 6	0.266	0.161	1.651
D * Material	D *ln M	beta 7	–0.288	0.270	–1.066
D * Labor	D * ln L	beta 8	–0.428	0.188	–2.281
D * LPIS	D * ln LPIS	beta 9	0.180	0.119	1.511
Inefficiency model					
		delta 0	–4.688	12.604	–0.372
		delta 1	–2.115	5.420	–0.390
		delta 2	0.096	0.918	0.104
Log likelihood function		–1.14E+02		LR. Test	1.34E+01

Source: authors' calculations

of the model which suggest that the farms operating in productive regions are more capital intensive and farms operating the LFA region are more labor intensive.

From the agricultural land point of view, the influence of agricultural land on technical efficiency was closely correlated with the quality of land in the selected production region. It could be noticed that one per cent increase of agricultural land has a different impact on the total production of Slovak farms. The estimated model has shown that there is a negative relationship between the increase of agricultural land and the level of technical efficiency in the LFA region. Farms operating in the LFA regions would slightly benefit in technical efficiency from the reduction of agricultural land. While one per cent increase of agricultural land of farms in the LFA regions would lead to the decrease in total production by 0.047 percent, different tendencies could be observed in the productive regions. One per cent increase would there lead to the increase of the total production by 0.133 percent.

Table 3. Descriptive statistics of technical efficiencies

	2003	2004	2005
LFA			
Mean	0.746	0.818	0.797
Standard deviation	0.117	0.066	0.101
Minimum	0.416	0.631	0.558
Maximum	0.877	0.895	0.912
PR			
Mean	0.747	0.807	0.731
Standard deviation	0.142	0.107	0.168
Minimum	0.253	0.442	0.253
Maximum	0.932	0.935	0.914

Source: authors' calculations

Analysis of technical efficiency

The descriptive statistics of technical efficiency which were estimated by Battese and Coelli (1995) model are presented in the Table 3. It is evident that the selected farms operating in the LFA regions achieved a higher level of the average technical efficiency. The significant differences in the average technical efficiencies between the productive and the LFA regions are observed only in 2005. Slovak farms in both production regions accomplished a significant

Table 4. Testing of significant differences of the average technical efficiencies

Within group differences			Between group differences		
	mean	*t*-test *P*-value		mean	*t*-test *P*-value
LFA 2003 LFA 2004	0.746 0.818	1.844E-05	LFA 2003 PR 2003	0.745606 0.747337	0.958
LFA 2004 LFA 2005	0.818 0.797	0.108	LFA 2004 PR 2004	0.817819 0.806572	0.568741413
PR 2003 PR 2004	0.747 0.807	6.642E-06	LFA 2005 PR 2005	0.797295 0.730805	0.032542062
PR 2004 PR 2005	0.807 0.731	9.345E-07			

increase in the average technical efficiency level in 2004 in comparison to 2003. The LFA regions achieved a higher increase in the average technical efficiency (9.65 %) in comparison with productive regions (8.03%).

The mentioned increase in the technical efficiency of Slovak farms in both production regions could probably be caused by the changes in the subsidy system and by better climatic conditions in 2004. In 2005, the decrease of the average technical efficiency of Slovak farms was noticed in both production regions. The decrease in the average technical efficiency was different in the investigated regions. While the LFA regions achieved only 2.57% decrease in the average technical efficiency, the productive regions were typical by the 9.42% decrease in 2005.

These facts could lead to the conclusion that the technical efficiency of the LFA regions was less influenced by climatic conditions and the changed subsidy system.

The verification of significant differences in the level of the average technical efficiencies is presented in the Table 4. From the Table 3, we can notice that there are significant differences in the average technical efficiency in the followed time period except for the Slovak farms in the LFA region in 2004–2005. From the production condition point of view, it is evident that there are no significant differences in the average technical efficiency. Significant differences in technical efficiency between both production regions are evident only in 2005. This situation could be explained by the substantial decrease of technical efficiency in the productive regions.

The interval distribution of efficiency measures of the productive and the LFA regions is shown in Figure 1 and Figure 2. Figure 1 illustrates the interval

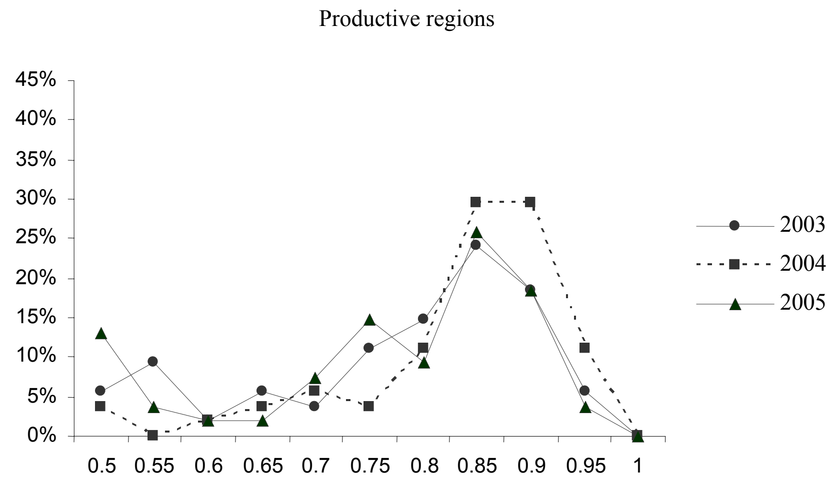

Figure 1. Distribution of technical efficiency of Slovak farms operating in productive regions

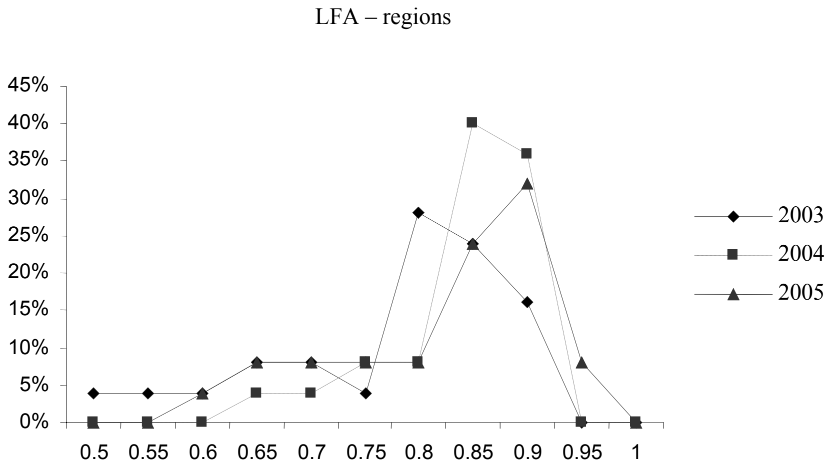

Figure 2. Distribution of technical efficiency of Slovak farms operating in LFA regions

distribution of the technical efficiency of Slovak farms in the productive regions. It could be observed that most of the Slovak farms in productive regions have achieved around 85% level of technical efficiency. It could be noticed that there are differences in technical efficiency between the investigated time periods in productive regions.

From the Table 3 and Figures 1 and 2, it is evident that a higher variation of technical efficiency is characteristic for the Slovak farms operating in productive regions compared with the farms in the LFA regions.

The farms operating in the LFA regions are typical by a lower level of the efficiency variability compared to the farms in productive regions. This fact is confirmed by the Table 3 and Figure 2, from which we can see that most of the Slovak farms in the LFA regions are concentrated in the interval of technical efficiency from 80% to 90%.

CONCLUSION

The presented empirical study utilized the stochastic parametric approach for measuring technical efficiency of Slovak farms operating in different production regions and time periods. From the methodological point of view, the one-stage model Battese and Coelli (1995) explaining technical inefficiency based on the farm-specific variable was used. This study is empirically implemented by using a panel data set of the 79 Slovak farms operating in the different production regions over the time period of 2003–2005.

The empirical findings indicate that the average technical efficiency of Slovak farms is different over the investigated time period. From the results of this study, the increase in technical efficiency of Slovak farms in 2004 within both production regions is evident. It could be caused by the changes in the subsidy system and by better climatic conditions in 2004. In 2005, a decrease of the average technical efficiency of Slovak farms was noticed in both production regions. The decrease in the average technical efficiency was different in the investigated regions. There were not observed any significant differences in the average technical efficiency between the different production regions. The noticeable difference in average technical efficiency of Slovak farms was evident only in 2005. We are aware of the low number data set which could have influenced the empirical results, because the quality of input data determinates the predictive power of the results. It may be interesting to compare the results of this study with the non- parametric approach in efficiency measurement (DEA).

REFERENCES

Battese G.E., Coelli T.J. (1995): A model for technical inefficiency effects in a stochastic frontier production function for panel data. Empirical Economics, *20*: 325–33

Bielik P., Pokrivčák J., Jančíková V., Beňo M. (2002): Natural, production and economic conditions of restructuring individual farm and enterprises in the Slovak Republic. Agricultural Economics – Czech, *48* (5): 211–214.

Bielik P., Rajčániová M. (2004): Scale efficiency enterprises in Slovakia. Agricultural Economics – Czech, *50* (8): 331–335.

Covaci S., Sojková Z. (2006): Investigation of whet efficiency and productivity development in Slovakia. Agricultural Economics – Czech, *52* (8): 368–378.

Fandel P. (2003): Technical and scale efficiency of corporate farms in Slovakia. Agricultural Economics – Czech, *49* (8): 375–383.

Farrell M.J. (1957): The measurement of productive efficiency. Journal o f the Royal Statistical Society, Series A (General), Part III, *120*: 253–290,

Gow H., Swinnen J. (1998): Agribusiness restructuring, foreign direct investment, and hold-up problems in agricultural transition. European Review of Agricultural Economics, *25* (4): 331–350.

Koopmans T.C. (1951): Analysis of production as an efficient combination of activities. In: Koopmans T.C. (ed.): Activity analysis of production and allocation. Wiley, NewYork.

Kumbhakar S.C., Ghosh S., McGukin J.T. (1991): A Generalised Production frontier approach for estimating determinants of inefficiency in U.S. dairy farms. Journal of Business and Economics Statistics, *9*: 279–286.

Murova O., Trueblood M.A., Coble K.H. (2001): Efficiency and Productivity Analysis of Ukrainian Agriculture, 1991–1996. Mimeo, Department of Agricultural Economics, Mississippi State University. Starkville.

Pitt M., Lee L. (1981): The measurement and sources of technical inefficiency in Indonesian weaving industry. Journal of Development Economics, *9*: 43–64.

Pokrivčák J., Ciaian P. (2004): Agricultural reforms in Slovakia. Financie a úver, *54* (9–10): 420–435.

Sojková Z (2001): Assessment of cooperatives efficiency using stochastic parametric approach. Agricultural Economics – Czech, *47* (8): 361–365.

Sotnikov S. (1998): Evaluating the effects of price and trade liberalisation on the technical efficiency of agricultural production in a transition economy: the case of R. European Review of Agricultural Economics, Oxford University Press for European Association of Agricultural Economists, *25* (3): 412–431.

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